SPECIFICATION

Electronic Version 1.2.8
Stylesheet Version 1.0

Composite Tank Stabilizer

Federal Research Statement

Not applicable.

Background of Invention

Field of Invention

[0001] This invention is directed to the field of fluid storage tanks fabricated from polymer matrix composites and more particularly to an apparatus for internally stabilizing and stiffening a thin shell tank structure using one or more stiffener struts possessing telescoping slip joints with limited compressive travel.

Prior Art

[0002] It is well known that polymer matrix composites (PMC) can be used for the manufacture of light-weight, high-pressure tanks. Such tanks may be used for the storage of cryogens such as LNG, LOX, LH2, and LN2. In a PMC tank, the material functions primarily in tension to contain the pressurized fluid. The tension results because the container shape as a sphere, domed vessel, or hemispherical headed cylinder tends to distribute internal pressures evenly due to diaphragm action as one might observe in a thin shell structure such as a balloon. Such thin shell structures are highly effective in their use of material.

[0003] A common fabrication technique for PMC tanks is to filament wind the primary tank structure upon a mold or liner frame mounted on a mandrel. Various designs for molds and liners that are either removable or become permanent liners are known in the prior art. Sand molds are a common support for the wound filaments of prepreg or tow. A problem with sand is its propensity to remain in the completed tank despite energetic washing.

[0004] Current practice is to utilize a metal alloy inlet connection for the tank. These inlet connections are often flanged and designed for easy connection to alloy piping. This practice requires a mating of the thin shell composite structure to the metal inlet in a metal transitional end structure called a boss. The alloy boss is welded to the inlet and makes a suitable support for the sand mold as well as an easy connection to a metal mandrel pipe or shaft used to hold and turn the boss and mold supporting structure securely during filament winding. These metal boss disrupt the smooth stress flow of the thin shell composite structure. In addition, the coefficients of temperature expansion are sufficiently different between alloys and composite materials to create major stresses leading to delamination between the two components when transitioned between ambient and autoclave temperatures during cross linking, and between ambient and cryogenic temperatures during operations. Currently, the weight of PMC tanks that carry cryogenic gases and fluids is severely handicapped by the addition of these heavy flanged metal end fittings. The weight of the metal boss can exceed 40% of the total tank weight.

[0005] With the introduction of Dynamic Polymer Composite (DPC) connectors in U.S. Patent No. 5,552,197, a flange-less method of connecting composites became available. With the advent of U.S. Patent No. 6,325,108, Prestressed Composite Cryogenic Piping, the use of alloy cryogenic piping was no longer mandatory. By these two teachings the justification for a heavy metal inlet was removed since PMC tanks can now be connected to PMC piping. Yet the prior art provides no teaching on the use of a composite boss as a form for filament winding to maintain precise dimensional tolerance without a sand casting. The prior art also offers no teaching for stiffening of a thin shell tank without creating stress concentrations and stress reversals in a thin shell tensioned membrane.

[0006] Removable mandrels are well known in the filament winding art, both for tanks and pipe. When removed, such a mandrel leaves the thin shell structure shape pliable. The tensioned membrane is left vulnerable to stress concentrations due to external support connections, or stress reversals due to shape distortion as a partially filled fluid load shifts. The alternative with removable mandrels is to increase the thickness of the shell to counter shape distortion. This compromises the weight advantage of the structure.

[0007] In the prior art Hoffmeister et. al. in U.S. Patent No. 4,561,568 discloses a tank assembly where a supply pipe passes through a first tank to an inner tank. In retrospect, this integral pass-through pipe can be considered a fixed stiffener. The resultant large increase in tank cross-section and weight at the inlet and outlet connections of this fixed pipe where it is connected to this small first tank are a vivid illustration within Hoffmeister Figure 1 of the problems in the prior art.

Summary of Invention

[0008] In order to overcome the deficiencies of the prior art the current invention, briefly stated, is a storage reservoir tank constructed by filament winding from polymer matrix composite materials having an internal stiffener connected to a boss so that the boss and the stiffener are compressively restrained during filament winding and fabrication and yet are also free to expand after fabrication during operation when the tank is pressurized with a cryogenic fluid.

[0009] The current invention also is described as an expandable composite tank cylindrical wall form comprising a first and second domed head form and boss selected to provide size, shape, and rigidity for the support of filament windings, connected to opposing ends of a pipe and telescoping slip joint assembly selected to provide limited compressive movement by abutting end surfaces within said slip joint and moment restraint during relative dimensional movement between said head forms.

Objects

[0010] It is a general object of the current invention to provide a light weight and stiffer PMC cryogenic tank.

[0011] It is another general object of the current invention to reduce the cost of tank fabrication.

[0012] It is a general object of the current invention to create a stable mandrel assembly incorporating the boss so that prepreg or fiber tow can be directly wound on the assembly without the use of a sand cast support for the filament winding.

[0013] It is an object of the current invention to provide a single central stiffener for the

support during filament winding of small diameter as well as multiple stiffeners for the support of large diameter boss that act as supporting forms.

[0014] It is an object of the current invention to provide that composite boss can be stabilized with struts to maintain precise dimensional tolerance as a form for filament winding using a composite boss.

[0015] It is another general object of the current invention to create a stable form for tanks that require a sand cast mandrel upon which to filament wind prepreg or tow so that precise dimensional tolerances are maintained during filament winding.

[0016] It is an object of the current invention to internally stabilize a thin shell composite tank for moment loadings from external connection to tank supports. Since the inlet pipe stub must often bear large external loadings, it is advantageous to carry these loads by an internal inlet pipe stiffener that traverses the axial diameter of a tank instead of strengthening the tank body over its entire surface to counter these loads. This is particularly true when the loads would distort the shape of the tank.

[0017] It is another object of the current invention to allow substantial compressive loads to be transmitted through the tank to the structural frame of a rocket or other system.

[0018] It is yet another object of the current invention to allow reinforcement of the tank for compressive loads without violating the nature of the thin shell composite tank structure by avoiding stress concentrations and reversal due to tension communicated from a fixed internal strut stiffener while the tank is under pressure. Pressure within a tank should develop a nearly uniform membrane tension over the entire tank surface. If a tank under internal pressure has a fixed internal strut, the tension stress would be an order of magnitude larger that the uniform membrane tension. Such strut stiffener tension restraint would act at ninety degrees to the membrane tension with the result that extreme stress concentrations and failure would occur at the intersection of the stiffener and the tank.

[0019] It will be understood by one skilled in the art that the slip joints may be located at any point along the length of a strut including the ends.

[0020] It will be recognized by one skilled in the art that the boss for the forming of a full

hemispherical headed tank without a sand casting form component may require addition stiffness in the form of ribs or other thickening of the cross-section.

Brief Description of Drawings

[0021] Fig. 1. is a center cross-section of a form to support filament winding of a fluid storage tank.

[0022] Fig. 2. is a cutaway of an elevation of a composite dome headed tank.

[0023] Fig. 3. is a cross-sectional view of two dome headed boss connected by multiple struts.

Detailed Description

[0024] Fig. 1. shows a composite tank stiffener after the teaching of this invention comprising at least one generally cylindrical pipe and strut 1 possessing at least one slip joint 2 integral with the other member 21 of the strut selected to provide (1) compressive dimensional limit 3,4 by abutting slip joint member surfaces 5,6 and (2) telescoping moment restraint during axial relative positional movement 8 due to congruent member slip joint wall surfaces 19, to resist an external moment indicated by arrows 7,said generally cylindrical pipe and strut 1 connecting and integral with the two internal faces 9,10 of two opposing composite boss 11,12 . This composite tank stiffener assembly is the mold portion of the mandrel for a filament wound tank 30 shown in Fig. 2.

[0025] Also in Fig. 1. the generally cylindrical pipe and strut 1 possesses at least one opening and inlet 13,14 for the transfer of fluids in common with fluid inlets 31,32 of said filament wound tank shown in Fig. 2.

[0026] Also in Fig. 2. the internal pressure 35,36 is shown acting upon the inside surfaces of the tank such as 40 to elastically stress and deflect them outward. This deflection has carried the two members 37,38 of the slip joint apart a measurable dimension 39. Yet members 37,38 maintain moment restraint because of congruent slip joint surfaces 41 during this axial relative positional slip joint member movement and at any position after axial relative positional slip joint member movement.

[0027] Additionally in Fig. 1 the generally cylindrical pipe and strut 1 also possesses openings 15,16,17,18. In Fig. 2 an equivalent opening 33 is shown in communication with the internal volume and reservoir 34 of said tank 30.

[0028] In Fig. 3. The internal faces 50,51 of two opposing boss 52,53 are connected at points 55-66 by multiple units of said generally cylindrical pipe and strut 67-72. Inlets 75,76 are integral with the boss 52, 53 and provide fluid access to the finished tank 30 (See Fig. 2.) after fabrication.

[0029] Such a composite tank stiffener consists of two opposing composite boss 52,53 that are selected of a size, shape, and strength to provide the supporting structure for the filament winding of the composite body of said filament wound tank 30 (See Fig. 2.).